Designation: D3387 – 11

Standard Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)[1]

This standard is issued under the fixed designation D3387; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This method employs a testing machine (Fig. 1) that generates a precisely controlled gyratory kneading process which is used to prepare and test specimens of bituminous paving mixtures. This method is intended for use in bituminous mixtures design and control testing as well as accelerated traffic simulation. The objective is to compact to the ultimate in place density under the anticipated vertical stress while monitoring the process in terms of unit mass, and shearing resistance including the plastic properties. Particular attention is given to the development of the plastic properties associated with the compaction phenomenon. The maximum permissible bitumen content is indicated directly by the first evidence of a progressive increase in shear strain (as indicated by a progressive increase in the gyratory angle) accompanied by a progressive reduction in shear strength (as indicated by a progressive reduction in roller pressure.) The procedures described here are for mix design and plant control as well as accelerated traffic simulation.

1.2 This test method covers two separate modes of operation of the Gyratory Testing Machine (GTM), namely: (1) GTM oil-filled roller mode; and (2) GTM air-filled roller mode. With the air filled roller, the GTM machine angle varies according to the resistance encountered during the gyratory kneading process. Thus the GTM using the air-filled roller is considered a better mechanical analog of the interaction between pneumatic tire and pavement structure.

1.3 This test method is for use with mixtures containing asphalt cement, asphalt binder cutback asphalt, asphalt emulsion. Test molds are available in 4- in. (101.6 mm), 6-in. (152.4 mm), and 8-in. (203.2 mm)diameters with corresponding height of 8-in (203.2 mm), 10-in.(254.0 mm), and 12-in. (304.8 mm) respectively. These molds can accommodate maximum particle sizes of 1 in. (25.4 mm) 1.5-in. (38.1 mm) and 2.0-in. (50.8 mm) respectively.

1.4 *Units*—The values stated in inch pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

E1 Specification for ASTM Liquid-in-Glass Thermometers

3. Terminology

3.1 *Definitions:*

3.1.1 *Critical roller pressure, p'*—the roller pressure required for a Gyratory Shear Factor (GSF) equal to unity. That is, the roller pressure when SG = τmax. (See Annex A1.)

3.1.2 *Equilibrium density*—density when a rate of densification of 1 lb/ft^3 (16 kg/m^3) per 100 revolutions of the GTM roller carriage is reached. This rate of densification is intended to duplicate the ultimate in place density.

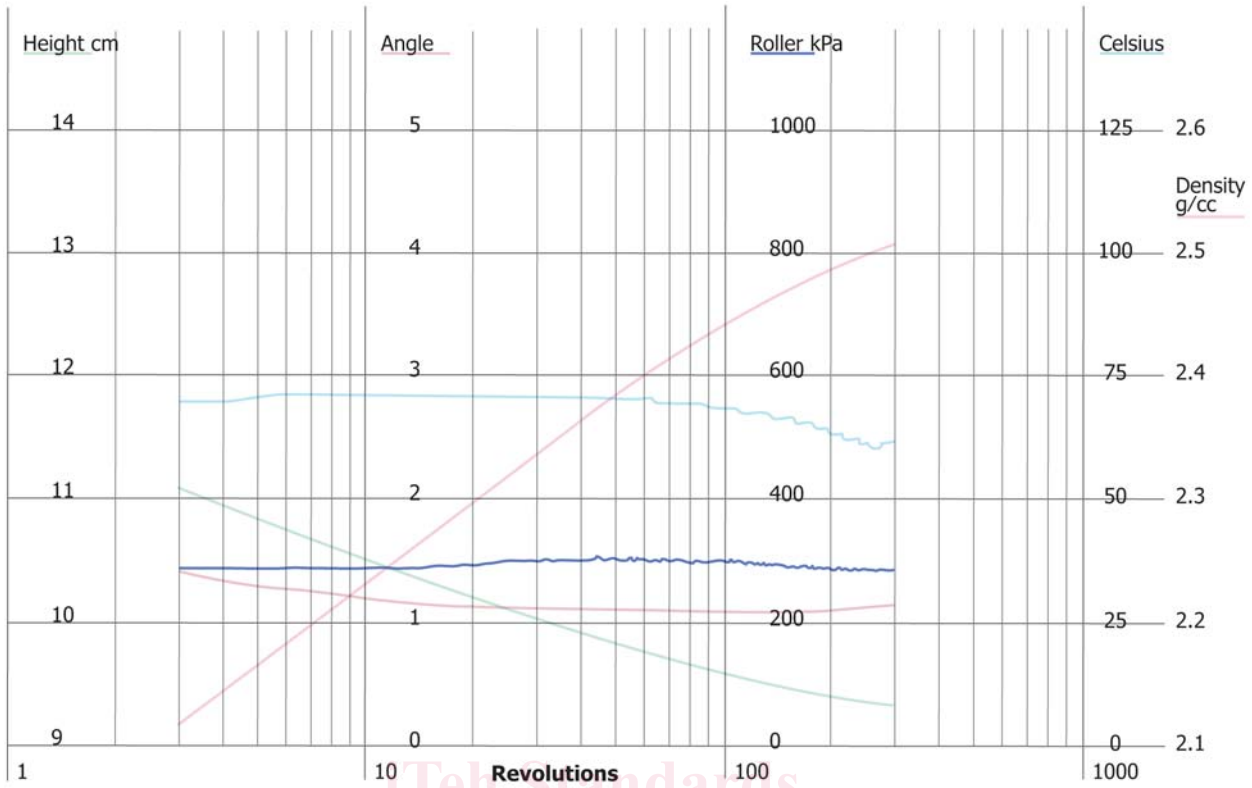
3.1.3 *Gyratory Angle*—measure of the magnitude of the gyratory strain θ. Four pertinent angles are defined as follows:

3.1.3.1 Machine angle (machine setting) θ_0.

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.26 on Fundamental/Mechanistic Tests.

Current edition approved Aug. 1, 2011. Published September 2011. Originally approved in 1974. Last previous edition approved in 2003 as D3387 – 03. DOI: 10.1520/D3387-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



GTM Compaction and Shear Test

Date - 7/19/2006 Time - 17:39:06 TestNumber - 389 (Re-Print from data file)
KETI AC-13 4.4-2
2006-7-19 qouya xiao
Mold Diameter = 10 cm
Total Specimen Weight in grams = 1900.0 Percent Bitumen (Total Wt) = 4.4

Compaction Stress in kPa = 800 Revolutions at end of Compaction = 300
Compaction terminated at equilibrium
Specimen Height in cm at end of Compaction = 9.344
Unit Weight Total Mix in g/cu cm = 2.5082
Unit Weight Aggregate Only in g/cu cm = 2.3978 O-rings not used in mold
Gyratory Compatibility Index D30/D60 = 0.97
Total Work Done in NM = 14226

Oil Cell Machine Angle in degrees = 0.85
Intermediate Gyratory Angle in degrees = 1.10
Gyratory Angle at end of Compaction in degrees = 1.15
Gyratory Stability Index GSI = 1.05

Average Roller Pressure in kPa at end of compaction = 288
Static Shear Strength in kPa = 313 Taumax in kPa = 255
Gyratory Shear Factor GSF = 1.23
Static Shear Modulus in kPa = 21077
Static Compression Modulus in kPa = 63232 Mu = .5

FIG. 1 Largest Model of Gyratory Testing Machine

3.1.3.2 Minimum gyratory angle or shear strain θ_{min}.

3.1.3.3 Maximum gyratory angle or shear strain θ_{max}.

3.1.3.4 Final gyratory angle θ_f. This is the angle at the conclusion of test.

3.1.4 *Gyratory Compactibility Index* (GCI)—the ratio of the unit mass (total mix) at 30 revolutions of the GTM to the unit mass (total mix) at 60 revolutions of the GTM.

3.1.5 *Gyratory Compression Modulus (Eg)*—a calculated value based upon the gyratory shear modulus Gg and a measured or assumed value of Poissonś ratio μ. Eg = 2 Gg (1 + μ).

3.1.6 *Gyratory Shear Factor* (GSF)—the ratio of the measured gyratory shear strength to the theoretical maximum induced pavement shear stress; SG / τmax. This is a factor of safety type index with regard to failure in simple shear for the defined loading conditions. The GSF value is not applicable when GSI > 1.0.

3.1.7 *Gyratory Shear Modulus (G_g)*—The gyratory shear SG divided by the gyratory shear strain tanθ, ($G_g = S_G / tan\ \theta_0$).

3.1.8 *Gyratory Shear Strength (S_G)*—the shear resistance of the specimen which is, among other things, a function of the imposed vertical pressure and degree of strain. The S_G value is influenced by the characteristics of the aggregate, binder and level of densification achieved.

3.1.9 *Gyratory Stability Index* (GSI)—the ratio of the maximum gyratory angle to the minimum gyratory angle $\theta_{max}/\theta_{min}$.

4. Significance and Use

4.1 The GTM test method described here is intended to be used to determine the maximum allowable bitumen content, establish unit mass requirements, and arrive at a rational shear strength. The GTM is also used to conduct accelerated traffic simulation. It is essential that the vertical pressure corresponds to the maximum anticipated vertical contact pressure between tire and pavement, since the theoretical stress for compaction and maximum induced shear is based on the concept of employing maximum anticipated loads.

4.2 The use of this method fin the selection of the optimum bitumen content is limited to mixtures that are susceptible to the development of excess pore pressure when the voids become overfilled with bitumen. This applies to dense graded HMA but does not apply to SMA mixes or to open graded friction courses. (This restriction does not apply to the gyratory strength factor, GSF.) A gyratory stability index (GSI) in excess of unity, overfilled voids and therefore serves to establish the maximum permissible bitumen content. The optimum bitumen content should be selected at a value of GSI equals one. This is established by interpolation of a graph of GSI vs. bitumen content. An increase in this index indicates an excessive bitumen content for the compaction pressure employed and foretells instability of the bituminous mixture for the loading employed. A reduction in roller pressure during the compaction process likewise indicates loss of stability because of overfilled voids; this phenomenon also serves as an indicator of maximum allowable bitumen content as does the increase of gyratory angle which gives a stability index in excess of unity.

4.3 It must be pointed out that the gyratory angle, being a measure of shear strain, is highly sensitive to temperature, especially on the rich side of optimum where the voids are overfilled and the shear stress is being transferred to the bituminous phase. Also, once the voids become over-filled, the bituminous mixture is subject to the phenomenon that may be best described as "stress-softening", that is flattening of the stress-strain curve (reduction in stability) with continued kneading. Attempts to relate GSI values to performance is not recommended other than to identify the maximum permissible bitumen content as that at which the GSI value starts to exceed one.

NOTE 1—The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Standard Practice D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with D3666 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of D3666 or some similar acceptable guideline provides a mean of evaluating and controlling some of those factors.

5. Apparatus

5.1 *Gyratory Testing Machine (GTM) and Appurtenances*—The primary equipment for this test is the Gyratory Testing Machine (GTM) and appurtenances. Fig. 1 is a photograph of the largest model GTM which is equipped to test 4-in. (101.6 mm), 6-in. (152.4 mm), or 8-in. (203.2 mm) specimens. Refer to manufacturer's manual for more information.

5.2 Supplementary Equipment – the following conventional materials testing laboratory equipment will be required:

5.2.1 *Ovens*—Ventilated ovens shall be provided for heating aggregates, bituminous material, and specimen molds and for curing cut-back mixes and emulsion mixes. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 5°F (2.8°C).

5.2.2 *Balances,* one having a capacity of 5 kg or more, sensitive to 1.0 g and one having a capacity of 2 kg, sensitive to 0.1 g.

5.2.3 *Thermometers*—Armored glass or dial-type thermometers with metal stems are recommended. A range from 50 to 400°F (9.9 to 20.4°C) with sensitivity of 5°F (2.8°C) is required.

5.2.4 *Miscellaneous Apparatus*—Trowels, spatulas, scoops, spoons, gloves, rubber gloves, metal pans.

6. Test Specimens

6.1 Refer to manufacturer's manual for detail information.

6.2 Prepare at least three specimens for each combination of aggregate and bitumen. Include a range of bitumen contents so as to fully develop the compaction curve, develop a smooth curve of GSI vs. bitumen content and have at least three bitumen contents in which the gyratory angle shows progressive increase with continued compaction. Conduct check tests on outliers as necessary to insure smooth curves of density, GSI and gyratory shear vs. bitumen content.

FIG. 2 GTM Compaction and Shear Test

6.3 *Preparation of Aggregates*—Separate the aggregate into the various size fractions necessary for accurately recombining into test mixtures conforming to specified grading requirements.

6.4 *Preparation of Mixtures*—Combine the freeoven-dried aggregates into appropriate size batches. See 6.6 for size of compacted specimens. Heat the aggregate to the desired temperature, into the aggregate mixture. Mixing of the aggregate and bitumen shallshould be as thorough and rapid as possible; mechanical mixing is recommended.

NOTE 2—For estimating purposes use 156.0 pounds/cubic foot (2.5 Mg/m^3) as the unit weight of compacted specimen.

6.5 For mixes employing penetration/viscosity/PG grades of asphalt, the temperature of the aggregate and asphalt at the